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Who benefits from training and R&D: The firm or the workers?
A study on panels of French and Swedish firms

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Abstract

The present paper offers a novel study of the effects of intangible assets on wages and productivity. Training, R&D, and physical capital are all taken into account, and their joint effects are examined. We use panels of firms in order to control for unobserved fixed effects and the potential endogeneity of training and R&D, and have been able to obtain data for two different countries, France and Sweden. The estimation of productivity and wage equations allows us to show how the benefits of investment in physical capital, training, and R&D are shared between the firm and the workers. Although the workers obtain significant benefits, the study shows that the firm obtains the largest return on the investments it makes. This is true not only for physical capital, but also for R&D and training.

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1. Introduction

Economists have long recognized the role of intangibles assets like knowledge and human capital as the engine of economic development. A large number of theoretical and empirical studies show that human capital, accumulated by education and training, and knowledge on new products and processes, generated by R&D activities, is the main source of growth in output in the long run (for an extensive study, see Aghion and Howitt, 1998). The R&D investment literature has focused on the effects of spillovers: a firm is likely to get only a part of the benefits of innovations it generates because other firms and consumers will also benefit through knowledge spillovers and various forms of externalities. Thus, the private rate of return will be lower than the social rate of return and this will lead to underinvestment in R&D activities. However, this literature does not pay sufficient attention to the fact that the employees of the innovating firms may also share these benefits[2].

The focus of the literature on investment in training (firm sponsored training) is the effect on workers' wages and careers. However, the primary aim of training is to increase productivity. This emphasis on wages comes from the dominant position of human capital theory in labor market research that stresses the supply of labor. It has been reinforced at the empirical level by the availability of data on wages, and the lack of data on training expenditures. The human capital theory also implies that workers are paid their marginal productivity, even though this is true at best over a long period. Recorded increases of wages with tenure are then interpreted as effects of (specific) training. As for general training, it could only be financed by the workers themselves. It should be immediately reflected in their wage as a result of perfect competition in the labor market. There would (by assumption) be no additional returns for the firm. Important policy conclusions follow from this view. Because of the externality, firms underinvest in training activities, and since workers are financially constrained, there is an under-provision of training in the economy, and a case for (costly) government subsidies, or a levy on firms to fund training, as in France.

The quantitative importance of training expenditures sponsored by firms and by governments implies a burden on the resources of the nations. This has raised demands for more direct measures of the productivity impact of training. There are debates about the efficiency of the training systems, and the reform of these systems has become a contested political issue, for instance in France (Gauron, 2000). Simultaneously new theories have been developed to justify that firms can rationally sponsor general training because they can retain part of the returns[3]. However, there is little empirical work on how the benefits (productivity increases) are shared by the firm and its workers. The lack of panel data on training activities at the firm level is one reason (for a comprehensive survey, see Blundell *et al*., 1999).

The present study offers some novel findings on the effects of training and R&D activities on the productivity of the firm, and returns to these activities. *First,* it uses longitudinal information on training and productivity at the firm level. This allows us to control for unobserved fixed effects and the potential endogeneity of training. S*econd,* it deals simultaneously with the effects of another important intangible investment of the firm, namely R&D. *Third,* it computes the effects of these factors, as well as physical capital, on both wages and value added. This allows us to compute the shares of the benefits that accrue to the firm, and to the workers respectively when the firm invests in any one of these factors, taking the joint effects of the others into account[4]. *Fourth,* we are able to present results for two countries, France and Sweden, to provide some control for country or institution specificity. To the best of our knowledge, this is the first study that analyzes how the returns to tangible and intangible assets are shared by firms and their employees by using panel data at the firm level.

The main result we obtain is that firms indeed obtain the largest parts of the returns to their investments, but the firms' share is lower for intangible assets, R&D and training. In France and Sweden, respectively, the firms obtain a very high proportion of the returns to physical capital (about 90 %), a large part of the returns to training (65 – 70 %), and a significant part of the returns to R&D (50 and 75 %) even though the total returns are quite different between the countries and between R&D and training.

Section 2 reviews briefly the literature on training and productivity since the issue of the returns to training is less well explored than the returns to R&D or physical capital. Section 3 describes the data. The empirical model and estimation results are presented in Sections 4 and 5, respectively. The main findings are summarized in Section 6.

2. The literature

Becker's influential study on human capital (Becker, 1964) has led to the accumulation of a voluminous literature on firms' and workers' investment in human capital, especially in the form of general and specific training. This literature has shown that the human capital stock of the firm accumulated through training activities is one of the main factors of production (for an extensive range of studies, see Lynch, 1994). Although the importance of human capital as a factor of production is strongly emphasized by almost all researchers, empirical studies have usually been confined to the analysis of the effect of training *on the wage rate* that is used as a proxy for productivity because it is *assumed* that the (real) wage rate will be equal to the marginal product of labor if the labor market is competitive. This assumption is, of course, very restrictive, and rules out the possibility that firms may invest in general training even if workers capture a part of the returns to that investment. As shown, among others by Acemoglu and Pischke (1998, 1999a and 1999b), Bishop (1991 and 1996), Loewenstein and

Spletzer (1999), and Booth and Snower (1996), there is strong evidence that suggests that firms provide general training to their workers (the classical example is the German apprenticeship programs) and share the benefits of (general and specific) training with their workers.

One needs to estimate both the productivity and wage equations to find out if firms and workers really share the benefits of training, and, in this manner, of other types of investment. The literature does not deal fully with the topic but offers some evidence that we will summarize now for the Anglo-Saxon data first, and then for the French and the Swedish data.

Early studies by Barron, Black and Loewenstein (1989), Holzer (1990), and Bishop (1991) are unique in that they use the Employment Opportunity Pilot Project (EOPP) Survey of Firms data set in which data on training were collected from employers and include information on both formal and informal training. A comparison of the effects of increased training on wage and productivity growth as estimated in these studies suggests that about half of the returns to training are received by workers. Bartel (1995), Barron, Berger and Black (1997), and Groot (1999) also estimated productivity and wage equations at the individual level and find substantial productivity effects. The main disadvantage of these individual-level studies is the use of (subjective) productivity scores assigned by employers in productivity equations.[5]

In recent years a number of researchers have sought to measure the effect of firm sponsored training on productivity using firm-level data. For example, Holzer *et al.* (1993) used data on firms that applied for training grants under the Michigan Job Opportunity Bank-Upgrade program in the late 1980s (three-years of data), and found that training has a positive effect on the quality of output (measured by the overall scrap rates), but effects on sales and wages are not significant. Bartel (1994) found a positive effect of training on productivity in her cross sectional analysis on about 150 firms from the Columbia Business School Survey. Black and Lynch (1996) used the National Center on the Educational Quality of the Workforce National Employers' Survey (821 establishments in manufacturing and 525 in non-manufacturing in 1993). Results of estimating Cobb-Douglas production functions for manufacturing and non-manufacturing sectors indicate that the average educational level of workers has a positive effect on sales in both sectors, but training (defined as the number of workers trained in 1990 and 1993) has no effect; the proportion of time spent in formal off-the-job training has a positive effect in manufacturing, and computer training has a positive impact in non-manufacturing. The econometric study by Boon and van der Eijken (1997) on a balanced panel of 173 Dutch firms confirms the importance of training as an input in the production function. Barrett and O'Connell (2001) estimated a labor productivity growth equation for a cross section of 215 firms in Ireland (all sectors including manufacturing and services), and found that general training has a positive impact on productivity growth but specific training has no effect. They also estimated that the interaction between investment and general training variables has a positive coefficient, i.e., the impact of general training varies positively with the level of capital investment.

There are some studies that use more aggregated data at the industry level. For example, Blakemore and Hoffmann’s (1989) time series analysis of quarterly data on US manufacturing shows that the productivity increase is over twice the size of the wage increase caused by human capital accumulation as measured by job tenure. Dearden, Reed and van Reenen (2000) have investigated the effects of the proportion of trained workers on both productivity and wages in a panel of British industries. They estimated a production function with constant returns to scale to obtain the elasticity of value added per worker with respect to training (and other inputs), and a wage equation to obtain the elasticity of the wage rate with respect to training (and other inputs). These two elasticities allow them to calculate the net benefit of training for firms (or, to be more precise, for sectors) which is found to be positive, i.e., firms capture a part of returns to training.

Two new avenues of research have been opened in recent years. First a number of researchers have sought to measure the effect of human capital on productivity and wages using matched individual-firm data (for example, see Hellerstein and Neumark, 1998; Hellerstein, Neumark, and Troske, 1999; and Margolis and Salvanes, 2001). These studies use a rich set of variables on workers' demographic characteristics and educational levels, but lack data on employer sponsored training. Second the theoretical analysis of Holmström and Milgrom (1994) on the "complementarity of incentives" has emphasized the interest of joint policies to enhance the firm performance. If these policies may belong to different functions of the firm, there has been a particular empirical interest for the complementarities within the Human Resources Management practices (Ichniowski, Shaw, Prennushi, 1997). However it is difficult in this framework to evaluate the contributions of the different practices since they are numerous and often collinear. Clustering techniques are then used to measure the impact on performance and the specific role of training cannot be assessed[6].

Turning to the literature on French data, we should first note that no study seems to deal both with productivity and wages, and explore the issue of sharing. Carriou and Jeger's (1997) study covers over 10,000 French firms, for the period 1986-92. They estimate the impact of lagged training expenditures on value added for each year separately, and find it to be positive and significant. Delame and Kramarz (1997) also analyze longitudinal French data for 1982-87. Their contribution takes into account the individual features of the French system. French firms are compelled by a 1971 law on training to spend at least a certain percentage of the wage bill on training, or pay an equivalent tax to the Government. Delame and Kramarz distinguish between three categories of firms, those spending more than the legal minimum, those spending the minimum rate on training, and those spending less than the minimum on training and paying the difference as a tax to the Treasury. The effects of training on productivity are significant only for managers, engineers and technicians, and only for the first group of firms (which spend more than the minimum rate set by the law). This classification is interesting, but the authors have chosen to replace the training expenditures by a dummy for training categories in the regressions. A fortiori, no stock of training is computed. The study may thus underestimate the effects of training.

Ballot and Taymaz (1999) have studied the effects of training and R&D on profitability by using the same set of variables on French and Swedish firms. It is a cross-sectional study for 1989, but estimates simultaneously the determinants of current investment in training, profitability, and the average wage rate. They compute for each firm the capital stock represented by cumulated training investments in order to take into account the lagged effects of these investments. The results suggest that training has a positive effect on profitability, but that R&D has no positive effect. However the interaction between the two variables has a significant positive effect, at least in France. Firm sponsored training hence, would appear to be a significant source of profits as well as wages. The limitations of the study arise from the modest size of the sample (about a hundred firms in each country), and the absence of longitudinal data on firms in order to control for firm specific unobserved characteristics. Ballot, Fakhfakh and Taymaz (1998) use a panel of French firms (1987-93) and show that both the training stock and the R&D stock have a significant impact on value added. The returns to training are very high, but the effects on wages are not studied.

Several papers study the effects of training on wages. Goux and Maurin (1997, 2000) use a large sample of workers interviewed in 1993 to show that training does not have a very important effect if the wage policy of a given firm is controlled for. Fougère, Goux and Maurin (2001) find that training does not have a significant effect on wage careers. Beret and Dupray (1998) state that the selection effect explains most of the apparent impact of training on wages. These two separate sets pf French papers, on productivity and on wages, suggest that, contrary to what is currently believed, the firm may capture a large part of the returns to training.

As far as Sweden is concerned, Kazamaki-Ottersten, Lindh and Mellander (1999) have shown that training may reduce production costs significantly. Ballot, Fakhfakh and Taymaz (2001) confirm that training is a significant input in the production function in Sweden and France, and find a similar role for R&D, but they do not study the determination of wages. Regner (1994) focuses on wage equations and finds no evidence that employees pay for training and no substantial effects of training on wages. Braunerhjelm and Eliasson (1998) found that human-embodied knowledge significantly increases productivity and profitability in Swedish manufacturing firms.

3. The data

We have used comparable panel data sets of firms in France and Sweden. The French data set is a match of three sources for the same firms (Table 1). The first source is a panel of the "Human Resources Accounts" of 200 firms in the French industry, over the period 1981-93. This source also contains information on firm sponsored training, employment, hires, separations, and wages. Training is measured by the percentage of the wage bill devoted to continued training so that we are able to calculate annual training expenditures (at constant 1987 prices) and hours of training.

This indicator has a *flow* dimension. To make the best use of the available information, we have computed *stock* of human capital, H, by cumulating flows over 7 years, as follows:

$$H_{it} = \phi_{it} + \sum_{n=t-6}^{t-1} \left\{ \prod_{j=n}^{t-1} (1-\theta_{ij}) \right\} \phi_{in} \qquad [3]$$

H_{it} is the training stock of the firm in year t, ϕ_{in} the training flow in year n and θ_{it} is the separation rate (indexed by firm and by year). Our methodology is inspired by the techniques used to calculate physical capital, but the depreciation rate is here distinct for each firm and each year. The data set has therefore the advantage of attributing a higher level of training capital to firms in which turnover is low, for a given level of training expenditures. It takes into account essential and usually left out determinants of firm human capital[7].

The second data set includes is the data on financial accounts of a very large sample of firms for the period 1987 to 1993 (value added, physical capital, etc.).

The third data set is based on the Structure of Employment surveys and gives the number of researchers in the firm as a measure of the stock of R&D[8]. The Structure of Employment surveys cover the population of firms, or more precisely the population of plants (except the small plants), and we have been able to aggregate plants to get the data at the firm level.

The matched sample contains about 100 firms, and, owing to their large size (number of employees), they represent around 10% of French manufacturing employment. An important feature of the sample is the average decline of value added (-2%), and even turnover. This decline is mainly in the sub-period 1989-93, and dominates growth in 1987-89. The panel is unbalanced, and we have included, for our econometric work, firms that have made available their Human Resources Accounts for at least two years.

The Swedish data set is an unbalanced panel of about 250 large firms or divisions of firms, collected by the Federation of Swedish Industries and the Industrial Institute for Economic and Social Research (IUI) for the period 1987 to 1993 (see Albrecht *et al.* 1992). The Swedish economy is characterized by large firms, so that the sample covers almost all the large firms and around 50% of total employment in Swedish manufacturing. The training variable relates to training expenditures. "Training stocks" have been computed by cumulating the training expenditures. Separation rates are not available for individual firms in the data set. We have experimented with various rates of depreciation, and found that the estimation results are not sensitive to such an aggregate rate of depreciation. However, to preserve the similarity with the French data, we have adopted a yearly depreciation rate of 10% that is in the range of the mean separation rates in Sweden[9].

4. The empirical model

A manufacturing plant *i* at time *t* is assumed to have a Cobb-Douglas production function of the form

[1] $Q_{it} = A_{it} K^{\alpha}_{it} L^{\beta}_{it} R^{\delta}_{it} H^{\gamma}_{it} e^{\varepsilon it}$

where Q is the value added, K the (fixed) capital stock, L labor, R the R&D stock, H the human capital (firm sponsored training) stock, and ε the i.i.d. error term. In logs and dividing by L we obtain the following equation:

[2] $ln q_{it} = ln A_{it} + \alpha\, ln k_{it} + \delta\, ln r_{it} + \gamma\, ln h_{it} + (\alpha + \beta + \delta + \gamma - 1)\, ln L_{it} + \varepsilon_{it}$

All lowercase variables now denote "per employee" values. In this specification, a positive (negative) coefficient of the employment variables will indicate increasing (decreasing) returns to scale.

The technology variable is defined as

[3] $ln A_{it} = A_i + \Sigma\lambda_t D_t$

where A_i's account for unobservable firm-specific affects and D_t are time dummies that are used to control for technical change and exogenous macroeconomic shocks.

Previous studies for France and Sweden (Ballot, Fakhfakh and Taymaz, 1998 and 2001) and for Ireland (Barrett and O'Connell, 2001) show that interactions between various assets could be important. Therefore, in some estimations we also allow for interactions between fixed capital, R&D and training variables (k*r, k*h, and r*h).

Following Griliches and Mairesse (1997), we have used OLS, fixed effects, random effects and GMM to estimate the production function (see Arellano and Bover, 1995). GMM handles not only unobservable individual effects but also possible simultaneity (of different intangible capital variables for example). GMM estimators use variables in differences, to eliminate unobservable individual effects, and use lagged values (in levels) as instruments to correct for simultaneity bias. However, as emphasized by Griliches and Mairesse (1997), fixed effects and GMM estimators produce rather unsatisfactory results (low and often insignificant capital coefficient and unreasonably low estimates of returns to scale). Blundell and Bond (1998, 1999) show that the lagged levels of a series provide weak instruments for first differences. They suggest taking into account additional non-linear moment conditions which correspond to adding (T-2) equations in levels with variables in differences as instruments[10] (Ahn and Schmidt 1995). This so-called GMM-SYS estimator yields more reasonable results. Our estimation results also lead us to a similar interpretation of the merits of various estimators. Therefore, in Tables 2 and 3, we present only the GMM-SYS estimation results (our preferred model) and OLS results for comparison purposes[11].

The wage rate is determined by a bargain between the firm and workers. The Nash bargaining model indicates that there are three factors that determine the wage rate: the productivity of the firm, Q/L, the outside (fallback) wage rate, w^*, and the bargaining power of the workers, ϕ (see Appendix for the model). If the workers do not have any bargaining power ($\phi = 0$), they will not be any better off than the alternative ($w = w^*$). However, if the firm does not have any bargaining power ($\phi = 1$), the workers will capture all output ($w =$

Q/L). Thus, any investment in tangible as well as intangible assets may lead to an increase in the wage rate through its effects on productivity, bargaining power, and outside wage of workers.

Workers, if they have any bargaining power, will claim a part of the increase in profits generated by new investment, and raise their wage rates. However, even if the workers have no bargaining power, an investment in tangible and intangible assets may lead to an increase in wages if it increases the outside wage of the worker, w^*. This effect is, of course, discussed in detail in the human capital literature. For example, the investment in general training, once made, is sunk and it is embodied in the worker as human capital. Therefore, when the worker is employed by another firm, his productivity will be the same, and his wage will be higher. If the worker gets all the benefits of investment as a result of the wage increase, then the firm will not have any incentive for investment. The firm will sponsor investment only if it can recoup its investment cost.

The increase in the outside wage as a result of investment in tangible and intangible assets, first of all, depends on the transferability of the asset embodied in workers to other firms. The asset could be human capital accumulated through investment in training, or knowledge generated by R&D activities. If the knowledge or human capital is completely specific to the firm, then it will not be transferable to other firms, and it will not have any effect on w^*. Even if the knowledge or human capital accumulated as a result of investment is general, the increase in the outside wage could be less than the increase in output so that the firm may find it profitable to finance investment. For example, Acemoglu and Pischke (1999b) show that a range of frictions (search and informational asymmetries, efficiency wages, complementarities between general and specific skills, union wage setting and minimum wages) may make investment in general training profitable for firms.

We expect investment in training to increase the outside wage because a part of training could be general and this would lead to an increase in the wage rate in the investing firm. A similar effect can be expected for investment in R&D as well because part of the knowledge is embodied in workers who can use it productively in other firms.[12] Workers share rents generated by innovation. On the other hand, this effect will be weak, or even absent for investment in fixed assets because they are embodied in machinery and equipment in which the firm has clear, well-defined property rights.

The change in workers' bargaining power induced by investment in tangible and intangible assets is another factor that affects the wage rate. For example, if the bargaining powers of skilled and unskilled workers are different, an investment in training may increase the power of workers, and may lead to an increase in wages, because workers will get a larger share of the profit of the firm even if there is no change in outside wages. This may be relevant if training is firm-specific so that it may not have any impact on the outside wage. On the other hand, investment in certain assets, for example, in machinery and equipment, may reduce workers' bargaining power.

To summarize, the wage rate (w) depends on the bargaining power of workers (ϕ), the outside wage (w^*), and the level of labor productivity (Q/L). Since the bargaining power and the outside wage may also depend on especially the intangible capital of the firm that is partly embodied in workers, the wage rate itself is determined by those variables that are used in the production function (Q). Therefore, we substitute those tangible and intangible capital variables for the bargaining power and the outside wage in the wage equation which becomes exactly the same as the productivity equation but the dependent variable is replaced by the (log) real wage per employee (for a similar specification, see Dearden, Reed and Van Reenen, 2000).

The bargaining power and the outside wage are certainly affected by other variables as well. It is well-documented that a number of variables, such as the structure of the product market, the level of unionization, the system of collective bargaining (firm-level, sectoral, national, etc.), (the generosity of) the unemployment benefit system, the unemployment rate and macroeconomic conditions, play a role in determining the bargaining power and the outside wage (for a number of empirical studies that measure the bargaining power of workers, see Abowd and Lemieux (1993), Blanchflower, Oswald, and Sanfey (1996), van Reenen (1996), Hildreth and Oswald (1997), Margolis and Salvanes (2001) and Dobbelaere (2003) and references therein). In our estimation, these variables are controlled for, to some extent, only by using firm-specific fixed effects and time dummies because of the lack of relevant firm-level data.

5. Estimation results

The production function (productivity) and wage equations were estimated for France and Sweden. We present first the OLS results for comparison purposes (see the first columns in Tables 2-3). GMM-SYS results for the base model are presented in column 2. The coefficient of the log employment variables is statistically insignificant in all but in the productivity model for France. In other words, the technology used by our sample of Swedish firms exhibits constant returns to scale, whereas there are mild decreasing returns in France. There is no wage differential, after controlling for R&D and human capital, between small and large firms in both countries. Other variables (fixed capital, R&D, and training) have the expected impact on productivity and wages.

The third model (in column 3, Tables 2-3) includes the interaction between human capital and R&D variables. The interaction variable has a positive (and statistically significant) coefficient in all models, indicating the importance of complementarities between human capital and R&D activities for productivity, and for wages as well. The fourth model includes interactions between R&D and fixed capital, and human capital and fixed capital. The inclusion of these interaction terms does not have a significant impact on existing variable with the main exception of the human capital-R&D interaction variable in the Swedish productivity model whose coefficient now becomes insignificant. The human capital-fixed capital interaction variable has statistically significant and positive coefficients in the wage equations of both countries, but other interaction variables for the fixed capital do not exhibit a consistent pattern. This is likely to be a result of multicollinearity among interaction variables that lead to fragile estimates. Therefore, the third model (in columns 3) is our preferred specification.

The training and R&D elasticities of value added per employee are 0.173 and 0.054 for France, and 0.073 and 0.061 for Sweden, respectively.[13] The significant positive coefficient of the training-R&D interaction variable indicates that training (R&D) has a larger positive impact on productivity if the firm accumulates R&D capital (human capital).

Turning to the effects on wages, we observe that both tangible and intangible capital is positively correlated with wages. The positive elasticity of wages with respect to capital intensity (7.7% for France and 3.0% for Sweden) indicates that a part of productivity gains from capital investment is passed on to the workers in terms of higher wages either because of the bargaining power of workers, or because of an increase in the outside wage of workers. Training and R&D have also positive and statistically significant impact on wages, showing that the accumulation of human capital and R&D, even if the firm finances it, has favorable effects for employees. The magnitude of the elasticity of wages with respect to training is 13.1 % for France and 6.1 % for Sweden, somewhat smaller than the elasticity of labor productivity with respect to training. The R&D elasticity of wages is about 6.6 % for France and 3.5% for Sweden.

Since we observe strong positive effects of tangible and intangible assets on both labor productivity and wages, we need to compute the *net* effect of each asset on firm profitability (as measured by the difference between value added and the total wage bill). The net effect can be calculated by deducting the returns received by workers from the total increase in value added (the elasticity of labor productivity with respect to a given asset *minus* the elasticity of wages with respect to the same asset multiplied by the share of the wage bill in value added, around 41 % for France, and 43 % for Sweden).

The workers' share in returns to investment in fixed capital, R&D, and training in France and Sweden is depicted Figure 1. Most of the benefits of tangible and intangible capital accrue to the firm. More precisely, French workers obtain only 9 % of the returns to physical capital, 30 % of the returns to training, and 50 % of the returns to R&D. The Swedish workers get almost the same proportion of returns to physical capital (7 %), but receive about 35 and 25 % of the returns to training and R&D, respectively.

It is quite interesting to observe for both countries that workers' get a larger share of returns to R&D and training than returns to fixed capital. This finding cannot simply be explained by the rent-sharing hypothesis because if workers have any bargaining power, they will get a part of profit irrespective of its sources. The relatively high share of workers in returns to R&D and training can stem from the fact that knowledge and skills generated by R&D and training activities are largely embodied in workers, and they are transferable to other firms.

In order to test the robustness of our results, we have experimented with a number of additional variables and specifications. First, the human capital literature suggests that workers may be willing to accept lower wages during (general) training, and, therefore, share costs of training with the firm. In such a case, our estimates of returns to workers tend to be overestimated. [14] We include the value of training in a given year (TRAINING FLOW) to control for the effect of wage cutting during training periods (see column 5 in Tables 2 and 3). Contrary to the hypothesized effect, current training has positive coefficients in both productivity and wage equations in both countries (it is not statistically significant in the Swedish wage equation). Our estimation results suggest that the data do not reveal any significant wage decline during the training periods, and, therefore, the estimated returns to workers of training activities are not likely to be seriously overestimated.[15]

Second, changes in the composition of the workforce as a result of innovation and/or external shocks could be associated with the wage increases. For example, the firm, after a successful innovation, can increase its productivity, and may replace (older) workers with (younger) workers who are well-educated in new technologies, and demand higher wages. Similarly, the firm may shed less productive/low-wage labor as a response to a negative external (demand) shock. In both cases, the productivity and wages in the firm will increase, although the workers do not share benefits of any type of investment with the firm. In such cases, our estimates for the returns to the workers are likely to be overestimated. Unfortunately, we have data for turnover only for French firms, and the impact of turnover is estimated for that sample. The labor turnover (as a proportion to the number of employees) variable has the expected impact on productivity and wages: it has statistically significant positive coefficient in the productivity equation, and statistically significant negative coefficient in the wage equation. The higher turnover rate implies higher productivity and lower wages. However, it does not have any significant impact on other variables, i.e., our results seem to be not overestimated.

Finally, we also estimated the dynamic forms that include the lagged dependent variable as an explanatory variable, but results were qualitatively the same. We used some characteristics of the labor force (average age, average tenure at the firm, and the proportion of female employees) for France (unfortunately, comparable data are not available for Sweden) but the estimates for variables under consideration did not change much.

6. Conclusions

The literature contains only separate studies of the effects of assets, and especially training, on productivity and wages, and estimates of productivity are very rare. The two types of studies already gave some hints that workers may not capture all benefits of training even if human capital is completely embodied in workers, and that firms get a high return from their investment in human capital. The present paper is the first to offer, at the microeconomic level, a coherent investigation of the effects of intangible assets on wages and productivity, and allows us to present estimates of the way the benefits are shared between the firm and the employees. It confirms that the firm obtains the largest part of the profits in the investments it makes. The results are similar for France and for Sweden, which suggest that they are robust enough to be observed in different institutional environments.

The workers also benefit from investments in tangible and intangible assets. This raises interesting questions about the mechanisms that allow them to obtain some rents. Insider power, union power and incentive constraints may come into play to generate such a sharing of the returns, and suggest more complex stories than the standard human capital theory based on perfect competition.

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Appendix: Wage determination

Wage determination is modeled as a bargain between the firm and workers (see, for example, McDonald and Solow, 1981). The expected utility of a risk-neutral representative worker is defined as

[A1] $U_i = (L/N)w + ((N\text{-}L)/N)w^*$

where L is the number of employees, N the number of workers, w the (real) wage rate, and w* the outside option (for example the unemployment benefit, or the real wage rate the worker could can elsewhere). The ratio L/N defines the probability that the worker would be employed. The union and/or the group of workers objective is to maximize total utility:

[A2] $U = NU_i = Lw + (N\text{-}L)w^*$

The Nash bargain for risk neutral workers can be written as

[A3] $U - U^*$

where U* represents the fallback position of workers, i.e., $U^* = Nw^*$.

The firm's profit function is defined as

[A4] $\Pi = Q - wL$

where Q is real value added (the product price is normalized to 1). The fallback position of the firm is no profit. Then, the Nash bargaining solution can be found by maximizing the following Nash product (Ω) with respect to *w* and L:

[A5] $\max\ \Omega = (U - U^*)^{\phi}\Pi^{1-\phi}$

where ϕ is the relative bargaining power of the worker, $\phi \in \{0, 1\}$. Since $U - U^* = (w - w^*)L$, at the interior optimum, the following first order conditions hold:

[A6] $\partial\Omega/\partial w = 0 \Rightarrow \phi / (w - w^*) - (1\text{-}\phi)L / (Q - wL) = 0$

[A7] $\partial\Omega/\partial L = 0 \Rightarrow (\phi / L) + (1 - \phi)(Q_L - w)/(Q - wL) = 0$

where $Q_L = dQ/dL$.

Equation A6 can be re-written as follows:

[A8] $w = (1\text{-}\phi)w^* + \phi(Q/L)$

Equation A8 defines the wage equation. The wage rate depends on the productivity of the firm (Q/L), the bargaining power of workers (ϕ) and the outside wage (w^*). The effects of investment in tangible (fixed capital) and intangible assets (R&D and human capital) on wages can be obtained by differentiating the first wage equation with respect to the stock of the asset, S (S = K, R, H), which is given by

[A9] $w_S = [(1\text{-}\phi)\, w^*_S L + \phi_S (Q - w^*L) + \phi(Q_S - L_S (Q/L)\,] / L$

This equation decomposes the impact of investment in S on the wage rate into three components: First, the wage rate increases as a result of an increase in the fallback (outside) wage of the worker. Second, the wage rate increases (decreases) if the investment in S makes workers' relative bargaining power stronger (weaker). Finally, the workers can share a part of the increase in output if they have a positive bargaining power to begin with, i.e., $\phi > 0$.

Table 1. Descriptive statistics

Label	Variable definition	Unit	Average	Min	Max
France (n=527)					
LPROD	Productivity, VA per employee	1000 FF	216,7	50,5	3494,6
CAPITAL	Fixed capital stock per employee	1000 FF	99,9	5,0	5580,0
TRAIN	Training stock per employee	1000 FF	10,5	0,3	47,3
TRAIN FLOW	Annual training expenditures per employee	1000 FF	2,8	0,5	8,8
R&D	Proportion of researchers	(%)	2,0	0,0	33,0
EMP	Number of employees		2596	303	77448
WAGE	Annual average wage rate per employee	1000 FF	89,3	49,9	179,2
Sweden (n=987)					
LPROD	Productivity, VA per employee	1000 SEK	461,0	51,3	2710,6
CAPITAL	Fixed capital stock per employee	1000 SEK	380,0	22,7	5694,3
TRAIN	Training stock per employee	1000 SEK	7,7	0,2	69,7
TRAIN FLOW	Annual training expenditures per employee	1000 SEK	2,0	0,0	24,2
R&D	R&D stock per employee	1000 SEK	36,9	0,1	1184,6
EMP	Number of employees		639	20	21241
WAGE	Annual average wage rate per employee	1000 SEK	201,2	45,5	406,4

Note: Geometric averages are used.

Table 2a. Determinants of labor productivity in France

	OLS		GMM-SYS		GMM-SYS		GMM-SYS		GMM-SYS	
	Coeff	t-value	Coeff	t-value	Coeff	t-value	Coeff	t-value	Coeff	t-value
CAPITAL	0,263	9,85 **	0,327	25,60 **	0,349	57,50 **	0,321	40,70 **	0,276	20,60 **
TRAIN	0,131	3,55 **	0,194	25,00 **	0,173	21,40 **	0,224	14,40 **	0,118	5,47 **
R&D	0,135	6,98 **	0,071	10,80 **	0,054	18,00 **	0,045	11,50 **	0,024	3,58 **
TRAIN*R&D	0,067	2,36 ***			0,150	25,20 **	0,125	13,80 **	0,122	10,40 **
TRAIN*CAPITAL	0,076	2,58 **					0,244	38,50 **	0,255	18,60 **
R&D*CAPITAL	0,026	1,69 *					-0,003	0,53	-0,002	0,22
EMP	-0,007	0,40	-0,028	4,63 **	-0,036	6,18 **	-0,013	1,62	-0,017	1,74 *
TRAIN FLOW									0,228	9,49 **
n obs	527		527		527		527		526	
n firms	101		101		101		101		101	
Wald (joint)	348,2 **		4186,0 **		7827,0 **		5052,0 **		968,4 **	
d.f.	8		4		5		7		8	
Sargan			80,5		83,8		90,6		91,4	
d.f.			80		100		140		160	
AR(1)	30,20 **		-2,25 *		-0,05		-0,20		-1,94 *	
AR(2)	21,77 **		-1,03		-0,72		-0,22		-0,04	

Notes: All models include time dummies. The OLS model includes also sector and R&D dummies.

** (*) means statistically significant at the 1% (5%) level, two-tailed test.

Table 2b. Determinants of wages in France

	OLS			GMM-SYS			GMM-SYS			GMM-SYS			GMM-SYS		
	Coeff	t-value		Coeff	t-value		Coeff	t-value		Coeff	t-value		Coeff	t-value	
CAPITAL	-0,021	1,86		0,072	17,50	**	0,077	29,10	**	0,067	20,20	**	0,049	8,80	**
TRAIN	0,126	9,09	**	0,140	23,00	**	0,131	42,20	**	0,147	24,70	**	0,073	7,16	**
R&D	0,080	10,90	**	0,069	24,50	**	0,066	29,20	**	0,062	22,30	**	0,038	8,16	**
TRAIN*R&D	0,060	5,98	**				0,039	22,50	**	0,039	14,20	**	0,049	10,90	**
TRAIN*CAPITAL	0,000	0,01								0,011	3,11	**	0,024	6,29	**
R&D*CAPITAL	0,007	1,15								-0,013	8,97	**	-0,009	4,17	**
EMP	0,021	3,04	**	0,006	0,98		0,008	1,27		0,000	0,07		-0,001	0,11	
TRAIN FLOW													0,159	13,20	**
n obs	527			527			527			527			526		
n firms	101			101			101			101			101		
Wald (joint)	674,1 **			3579,0 **			12710,0 **			2677,0 **			3086,0 **		
d.f.	8			4			5			7			8		
Sargan				83,6			90,8			82,6			85,2		
d.f.				80			100,0			140,0			160,0		
AR(1)	27,03 **			-1,47			-1,66			-1,52			-3,55 **		
AR(2)	19,14 **			-0,07			-0,29			-0,24			-0,11		

Notes: All models include time dummies. The OLS model includes also sector and R&D dummies.

** (*) means statistically significant at the 1% (5%) level, two-tailed test.

Table 3a. Determinants of labor productivity in Sweden

	OLS			GMM-SYS			GMM-SYS			GMM-SYS			GMM-SYS		
	Coeff	t-value		Coeff	t-value		Coeff	t-value		Coeff	t-value		Coeff	t-value	
CAPITAL	0,208	11,30	**	0,179	11,20	**	0,176	11,40	**	0,173	14,60	**	0,177	18,10	**
TRAIN	0,081	4,63	**	0,073	3,87	**	0,073	4,87	**	0,065	5,82	**	0,046	6,30	**
R&D	0,057	5,10	**	0,063	5,81	**	0,061	6,83	**	0,055	11,40	**	0,060	13,40	**
TRAIN*R&D	0,005	0,48					0,018	3,42	**	-0,003	0,70		-0,002	0,38	
TRAIN*CAPITAL	-0,025	1,37								-0,045	4,66	**	-0,040	5,23	**
R&D*CAPITAL	0,030	2,58	**							0,050	9,95	**	0,049	9,48	**
EMP	0,013	0,92		-0,017	0,90		-0,008	0,46		0,006	0,46		-0,011	1,05	
TRAIN FLOW													0,011	3,81	**
n obs	987			954			954			954			954		
n firms	268			235			235			235			235		
Wald (joint)	247,7 **			181,7 **			210,8 **			489,7 **			735,6 **		
d.f.	8			4			5			7			8		
Sargan				84,9			107,9			151,1			173,8		
d.f.				80			100			140			160		
AR(1)	23,75 **			-3,21 **			-3,24 **			-3,27 **			-3,35 **		
AR(2)	16,20 **			0,04			-0,05			-0,45			-0,26		

Notes: All models include time dummies. The OLS model includes also sector and R&D dummies.

** (*) means statistically significant at the 1% (5%) level, two-tailed test.

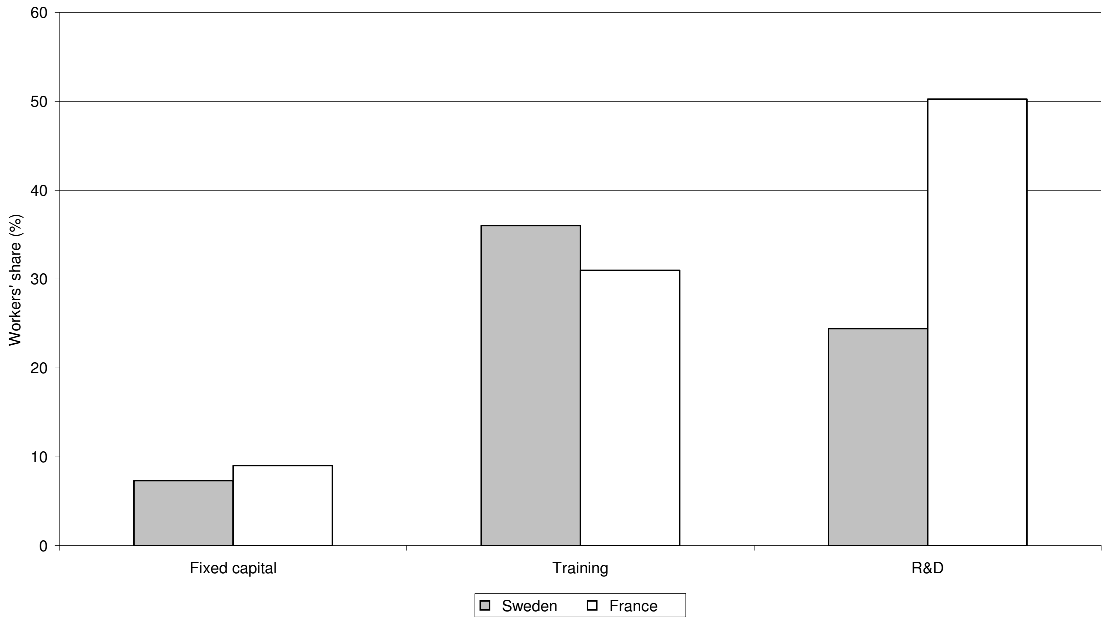
Table 3b. Determinants of wages in Sweden

	OLS		GMM-SYS		GMM-SYS		GMM-SYS		GMM-SYS	
	Coeff	t-value	Coeff	t-value	Coeff	t-value	Coeff	t-value	Coeff	t-value
CAPITAL	0,047	6,78 **	0,040	9,98 **	0,030	4,88 **	0,035	8,80 **	0,034	11,00 **
TRAIN	0,048	7,20 **	0,029	4,15 **	0,061	10,50 **	0,063	13,90 **	0,065	19,90 **
R&D	0,032	7,67 **	0,063	9,04 **	0,035	11,50 **	0,035	15,50 **	0,036	20,60 **
TRAIN*R&D	0,010	2,66 **			0,009	4,30 **	0,011	6,77 **	0,009	6,74 **
TRAIN*CAPITAL	0,016	2,34 **					0,014	4,48 **	0,013	4,39 **
R&D*CAPITAL	0,005	1,21					0,003	1,44	0,003	1,60
EMP	-0,001	0,19	-0,011	1,56	-0,004	0,57	-0,006	1,50	-0,017	5,03 **
TRAIN FLOW									0,002	1,78
n obs	987		954		954		954		954	
n firms	268		235		235		235		235	
Wald (joint)	233,1 **		336,9 **		417,5 **		926,2 **		1444,0	
d.f.	8		4		5		7		8	
Sargan			81,5		110,1		140,7		158,0	
d.f.			80		100		140		160	
AR(1)	10,85 **		-2,36 *		-2,39 *		-2,42 *		-2,43 *	
AR(2)	6,86 **		1,30		1,28		1,21		1,23	

Notes: All models include time dummies. The OLS model includes also sector and R&D dummies.

** (*) means statistically significant at the 1% (5%) level, two-tailed test.

Figure 1. Workers' share in returns to investment in fixed capital, training, and R&D



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[2] This issue is partly covered by the rent sharing literature; see for an excellent example, van Reenen (1996).
[3] See Acemoglu and Pischke (1998, 1999a) for comprehensive reviews of labour market imperfections, and Ballot (1994) for a hypothesis based on the innovation rent in the product market.
[4] The only similar study we know of is Dearden, Reed, and Van Reenen (2000), but they use data at the sector level.
[5] For example, in the EOPP Survey of Firms, employers were asked the following question. "Please rate your employee on a productivity scale of zero to 100, where 100 equal to maximum productivity rating any of your employees in that position can attain and zero if absolutely no productivity by your employee". Therefore productivity increases after a change in the worker's position cannot be estimated because productivity ratings are relative measures.
[6] For a recent work, see Guest, Michie, Conway and Sheehan (2003).
[7] Besides these losses, training capital undergoes obsolescence as time elapses. Since we have no measure of the rate of depreciation, we have tried with several uniform rates, and the results were not affected. Therefore we present results without obsolescence, but with depreciation due to separations.
[8] "The proportion of researchers in the firm" is used as a measure of the stock of R&D, because no direct measure of R&D stock is available. In our previous studies (see Ballot, Fakhfakh and Taymaz, 1998 and 2001) we used "the stock of R&D" as defined in the social accounts. The main problem of the data in social accounts is the fact that it does not cover all R&D performers, and, hence, cannot be matched with other data sets we use.
[9] Holmlund (1984, figure 2.4) finds a monthly separation rate of 9% (corresponding to an annual rate of 10.8%) in 1982 for white collar employees.
[10] T-2 equations coming from the moment restriction $E(\varepsilon_{it}\ \Delta\varepsilon_{it-1})=0$, where T is the number of years the firm is present.
[11] We use the DPD package for Ox [http://www.nuff.ox.ac.uk/users/ Doornik/].
[12] This effect may lead to a positive correlation between profits and wages in innovative firms even if workers have no bargaining power. For example, van Reenen (1996) shows that quasi rents generated by innovations are shared by workers in the British manufacturing firms. Our analysis indicates that if innovative activities enhance knowledge embodied in workers (which is certainly the case), then workers will have higher wages.
[13] Since all variables are used as deviations from their sample averages, the coefficients of training and R&D variables measure output/wage elasticities at the geometric mean of the sample.
[14] We thank Kathryn Shaw for her comments on these issues.

[15] When the current training variable is included, we observe a significant decline in the coefficient of the human capital variable, because current training expenditures (TRAIN FLOW) account for about 25 % of the human capital stock (TRAIN) in France and Sweden (calculated from Table 1).